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Review on Crop Diversity for Climate Change Adaptation

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Abstract
Climate change is real. Crop failure that declines productivity is also real. Extreme climatic condition that our farmers are facing is causing a drought, pests and other plant diseases. Ethiopian farmers are seriously vulnerable to the climate extremes. Their rain fall dependent agriculture left them in the situation under production loss.
In order to cope up with this harsh climate conditions it sounds great to change farming system. Given climate change and its adverse consequences are common; the farmers' capacity to adapt to the already existing climate extremes should be enhanced.Increasing crop diversity is one of the important ways of adapting to climate change. It is all about diversifying a type of crops in the farm. Different crops have different response to the climatic shocks, pests, diseases and other enemies. Drought resistant crops are those crops with high tolerance to the drought. Those crops save the household of poor farmers who are living in the subsistence life. Enset is an important drought tolerant endemic crop to Ethiopia. This golden crop is limited to southern part of Ethiopia and not widely distributed even inside the country. If experts of plant are engaged in the researches associated with this crop and its distribution throughout the country, it grants bulk loaves to those households under hunger due to climate change. Sorghum is another drought resistant crop in Ethiopia. Though it is already at the hand of the farmers, its improved variety has to be further introduced to the farmers in order to insure household's food security. Sweet potato is also invaluable crop in climate change adaptation. Its high productivity and great nutritional value support farmers to survive under climate change. Finally, I believe that, the combination of these and others important crops in the farm can help to adapt to the climate change. The diverse the crops, the less will be the production loss due to climate change
Keywords: climate change, crop diversity, climate change adaptation

1. INTRODUCTION

Many lines of scientific evidence show the Earth's climate is changing. It is worth noting that increasing global temperature is only one element of observed global climate change. Precipitation patterns are also changing; storms and other extremes are changing as well (NOAA, 2015).

The changing climate impacts society and ecosystems in a broad variety of ways. For example climate change can increase or decrease rainfall, influence agricultural crop yields, affect human health, cause changes to forests and other ecosystems, or even impact our energy supply. Climate-related impacts are occurring across regions of the country and across many sectors of our economy. http://www3.epa.gov/climatechange/impacts/ (Accessed date 12/10/2.16)

Climate change poses important challenges for agriculture and food security in Africa. It directly affects food production through changes in agro-ecological conditions and indirectly affects growth and distribution of incomes, and thereby, the demand for agricultural produce (ADFCC, 2010).

Diversification is one way to give farmers more options in times of need. With little access to a diversity of crops and varieties, farmers are more likely to cope with the effects of climate change. But farmers do not always have the information or planting material to choose what diversity best suits their conditions (Biodiversity International).

http://www.bioversityinternational.org/research-portfolio/adaptation-to-climate-change/seeds-for-needs/ (Accessed date 19/10/2.16)

Therefore, the objective of this paper is to review the role of crop diversity on climate change adaptation.

2. CLIMATE CHANGE

2.1 What is Climate Change

Climate change is a change in the statistical distribution of weather patterns when that change lasts for an extended period of time (i.e., decades to millions of years). Climate change may refer to a change in average weather conditions, or in the time variation of weather around longer-term average conditions (i.e., more or fewer extreme weather events). It is mainly caused by the anthropogenic activities while a natural causes shares its part (ACC, 2010).

USEPA glossary defines climate change as any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among others, that occur over several decades or longer. http://www3.epa.gov/climatechange/glossary.html#C (Accessed date 03/10/2.16)

Nicholas Stern (2006) stated that change is a serious and urgent issue. There is now an over-whelming body of scientific evidence that human activity is causing global warming, with the main sources of greenhouse gases, in order of global importance, being electricity generation, land-use changes (particularly deforestation), agriculture and transport; the fastest growing sources are transport and electricity.

2.2 Climate Change Adaption

Adaptation is the adjustment that society or ecosystems make to prepare for, or adjust to climate change. Adaptation can include actions by individuals and communities, from a farmer planting more drought-resistant crops to a city ensuring that new coastal infrastructure can accommodate future sea level rise. Many governments and organizations across the United States and the world have already begun taking action to adapt to climate change. Together, adaptations, coupled with actions to reduce greenhouse gas emissions, are essential to limiting the damages from future climate change (USEPA, 2015).

Adaptation to climate is not a new phenomenon. Indeed, throughout human history, societies have adapted to natural climate variability by altering settlement and agricultural patterns and other facets of their economies and lifestyles. Human-induced climate change lends a complex new dimension to this age-old challenge (Burton, 2006).

Nicholas (2006), describes the importance of the adaptation measures as ‘’Adaptation has the potential to reduce the impact of climate change. Over the next thirty years, substantial climate change is already inevitable, since mitigation will have only a minor effect on stocks of greenhouse gases in this time frame. So adaptation is an essential policy response, and the international community must find ways of supporting adaptation, especially in the most vulnerable countries.

There are significant new opportunities in the Green Economy for absorbing carbon from the air, and simultaneously generating green products. Changing agricultural practices and improving land use in Africa’s vast dry land areas is considered to be one of the cost effective ways of reducing atmospheric greenhouse gases. The restoration of degraded cropland soils can also increase soil carbon-storage and crop yields, while contributing to the conservation of agricultural biodiversity, including soil biodiversity. There is potential for global agreements to permit new ‘crops and products’ by tapping into new sources of funding through carbon trading and Reducing Emissions from Deforestation and Forest Degradation (REDD) (ADFCC, 2010).

2.3 Climate change in Ethiopia

Ethiopia has experienced at least five major national droughts since 1980, along with a large number of localized droughts (World Bank 2008). These cycles of drought create poverty traps for many households, constantly consuming their efforts to build up assets and increase income. About half of all rural households in the country experienced at least one major drought from1999 to 2004 (Dercon, 2009).

Agriculture in Ethiopia is heavily dependent on rain. It’s geographical location and topography, plus a low adaptive capacity, make the country highly vulnerable to the adverse impact of climate change. Poverty in Ethiopia is chronic problem and about two thirds of its people live on less than $2 a day. It is one of the most food insecure countries in the world; a situation is compounded by droughts and famine that cycle in and out.

According to the International Food Policy Research Institute (IFPRI) 2011, In Ethiopia, climate change is expected to intensify the already high hydrological variability and frequency of extreme events. More than changes in mean annual rainfall, these two factors may have a significant negative effect on the development of the agricultural sector and on the Ethiopian economy as a whole.

The same source indicated that, extreme hydrological variability and seasonality have constrained Ethiopia’s past economic development by negatively affecting crop production—chiefly through droughts—and by destroying roads and other infrastructure due to flooding. As climate change unfolds, average climatic variables will shift, and weather variability will intensify, exposing Ethiopian agriculture to higher levels of risk and jeopardizing economic growth, food security, and poverty reduction.

Zenebe et al (2011) stated that, the impact of climate change was assessed in terms of its effect on crop and livestock farming and how these effects extend throughout Ethiopia, in terms of economic growth and poverty reduction. Looking at two zones that dominate Ethiopia’s agricultural production today- the moisture sufficient areas with cereal based agriculture and the drought prone highlands – their projected outcomes are somewhat different, but climate change is expected to have a huge impact to both.

According to the Marius Keller (2009), climate change is already taking place now, thus past and present changes help to indicate possible future changes. Over the last decades, the temperature in Ethiopia increased at about 0.2°c per decade. The increase in minimum temperatures is more pronounced with roughly 0.4°c per decade. Precipitation, on the other hand, remained fairly stable over the last 50 years when averaged over the country. However, the spatial and temporal variability of precipitation is very high, thus at large scale trends do not necessarily reflect local condition.

According to African Development Bank (AfDB) the Ethiopian government’s existing policy and

institutional framework for natural resource management and the environment are adequate and sound. Policies are mainstreamed in sectorial programs which are implemented at the federal, regional and district (woreda) levels. Furthermore, the Growth and Transformation Plan recognizes poverty environment linkages and the importance of sound environmental management in sustainable development (http://sidaenvironmenthelpdesk.se/wordpress3/wp-content/uploads/2013/05/Ethiopia-Environmental-and-Climate-Change-policy-20130527.pdf (Accessed date 12/10/2.16).

Except for the lowlands and pastoralist areas, mixed crop livestock farming is the dominant farming type in Ethiopia. However, there have been few attempts to look into the economic impacts of climate change in the context of Ethiopia. Particularly, the role of livestock was disregarded in the previous studies.

Findings suggest that climate change can have significant negative impacts on Agriculture of Ethiopia, unless appropriate adaptation measures are adopted. Moreover, increasing/decreasing rainfall associated with climate change is damaging to both crop and livestock agricultural activities (Zenebe et al, 2014).

2.4 Climate Change Adaptation in Ethiopia

Like in any other parts of the world, Ethiopians have always adapted to variations in their climate, by making preparations based on their resources and their knowledge accumulated through experience of past weather patterns. Periodically, they have also been forced to react to and recover from climate extremes and surprises, such as floods and droughts. Adaptation is recognized as a critical response to the impacts of climate change, because current agreements to limit emissions, even if implemented, will not stabilize atmospheric concentrations of greenhouse gases and climate change. Adaptation can reduce present and future losses from climate variability and change. It is neither a one-off intervention nor a stand-alone activity. It is rather a process that needs to be incorporated in the overall development planning, including the design and implementation of projects and programs across relevant sectors (FDRE MoWRMA, 2007).

Agricultural technology development and promotion strategy/theme includes development of drought resistant/tolerant varieties of crops and irrigation schemes being conducted at various federal and regional research centers and promoted to drought-affected areas of the country. These drought resistant/tolerant/escape crop varieties significantly increased production and productivities and thereby reduced vulnerability to climate change (FDRE MoWRMA, 2009).

According to FDRE MoWRMA, 2007 Potential adaptation option in Agriculture & rural development sector:

- Introduce programs/projects that promote improved farming practices, drought resistant & early maturing crop varieties & supply inputs that increase crop yield & productivity
- Improved land management, moisture & soil conservation & flood control method in both the high & lowland areas
- Develop improved water use (water harvesting, small-scale irrigation, etc) in drought prone areas to alleviate rain shortages that cause crop failure
- Improve farmers' knowledge about proper use of weather information in carrying out agricultural activities to avoid risks of climate change.
- Introduce off – farm activities to increase alternative household income sources

2.5 Impacts of Climate Change

The changing climate impacts society and ecosystems in a broad variety of ways. For example climate change can increase or decrease rainfall, influence agricultural crop yields, affect human health, cause changes to forests and other ecosystems, or even impact our energy supply. Climate-related impacts are occurring across regions of the country and across many sectors of our economy. http://www3.epa.gov/climatechange/impacts/ (Accessed date 12/10/2.16)

The effects of climate change will be felt by the entire nation:

- All sectors of the economy - most notably agriculture, energy, and transportation - will be affected;
- Essential infrastructures that afford us reliable services and high standards of living (such as water supply and water treatment) will be impacted; and
- Ecosystems, on which quality of life relies (such as forests, rivers, and lakes), will suffer (CIER, 2007).

According to the Burton (2006), the production of food crops is the most climate-dependent economic activity. Changes in climate can be expected to have significant impacts upon crop yields through changes in both temperature and moisture. As climate patterns shift, changes in the distribution of plant diseases and pests may also have adverse effects on agriculture.

2.6 The impact of climate change on crop productivity

Higher temperature causes faster crop development and thus shorter crop duration, which in most cases is associated with lower yields (*Stone, 2001*). Temperature impacts the rates of photosynthesis, respiration, and

grain filling. Crops with a C4 photosynthetic pathway (e.g. maize and sugarcane [Saccharum officinarum]) have higher optimum temperature for photosynthesis than C3 crops (e.g. rice and wheat), but even C4 crops see declines in photosynthesis at high temperature Warming during the day can increase or decrease net photosynthesis (photosynthesis-respiration), depending on the current temperature relative to optimum, whereas warming at night raises respiration costs without any potential benefit for photosynthesis (*Crafts-Brandner and Salvucci, 2002*).

Climate variability is one of the most significant factors influencing year to year crop production, even in high-yield and high-technology agricultural areas. In recent years, more and more attention has been paid to the risks associated with climate change, which will increase uncertainty with respect to food production (V.R. Reddy and Y.A. Pachepsky, 2000).

The likely impacts of climate change on crop yield can be determined either by experimental data or by crop growth simulation models. To predict future impacts on crop yields, crop models present valuable approaches (P.K. Aggarwal, *et al.* 2006).

Climate change impacts on crop yield are different in various areas, in some regions it will increase, in others it will decrease which is concerned with the latitude of the area and irrigation application (Yinhong Kang and Shahbaz Khan, 2009).

The same source indicated that, climate change impacts on crop yield are often integrated with its effects on water productivity and soil water balance. Global warming will influence temperature and rainfall, which will directly have effects on the soil moisture status and groundwater level. Crop yield is constrained to crop varieties and planting areas, soil degradation, growing climate and water availability during the crop growth period. With temperature increasing and precipitation fluctuating, water availability and crop production will decrease in the future.

Crop production is one aspect of the food systems affected by climate change. It is very pertinent to look at how climatic change would affect crop production in SSA. This is because crop production does not only look at how the crops we consume are produced, but it is also an employer of labour especially in Sub Saharan Africa where over 70 percent of the people depend on farming for their livelihoods (Oyiga et al, 2011).

Climate change will alter potential losses to many pests and diseases. Changes in temperature can result in geographic shifts through changes in seasonal extremes, and thus, for example, overwintering and summer survival. CO2 and O3 can either increase or decrease plant disease, and can exhibit important interactions (Chakraborty and Newton, 2011).

2.7 Farmers vulnerability to climate change in Ethiopia

Ethiopia is one of the poorest countries in the world and 85 percent of the population depends on agriculture for their livelihood. The agricultural sector is especially vulnerable to the adversities of weather and climate since it is rain fed, done using relatively basic technologies, and on tiny plots of land (https://www.oxfam.org/en/pressroom/pressreleases/2010-04-22/climate-change-increasing-poverty-and-vulnerability-ethiopia(Accessed date 14/10/2.16).

Ethiopia's agricultural sector, which is dominated by small-scale, mixed crop, and livestock farming, is the mainstay of the country's economy. Ethiopia's dependence on agriculture makes the country particularly vulnerable to the adverse impacts of climate change on crop and livestock production (Temesgen et al, 2008).

According to the source, generally, increased frequency of droughts and floods negatively affects agricultural production, demonstrating agriculture's sensitivity to climate change.

According to the Oxfam international report published on 22 April 2010, "Even relatively small shifts in the growing season, can spell disaster for the poorest farmers and pastoralists who are already struggling in poverty." "The rain doesn't come on time anymore. After we plant, the rain stops just as our crops start to grow. And it begins to rain after the crops have already been ruined," Sefya Funge, a farmer in Adamitullu Jiddo Kombolcha district in Ethiopia told Oxfam.

Low agricultural productivity and recurrent food insecurity have already put Ethiopia in a precarious situation, which will only be exacerbated by climate change and variability (Mahoo H. et al, 2013). Clearly Ethiopia is highly vulnerable to current variability and there are also indications that climate change will increase rainfall variability which will likely increase losses from rain-fed agriculture. Poor rural people are the most vulnerable to the effects of climate change. Many live on ecologically fragile land and depend on agriculture, livestock, fisheries and forestry. Poor rural people do not have the access to financing and infrastructure that would allow them to withstand the impact of climate change (Ayana et al, 2011).

According to the similar source, vulnerability assessment of the agriculture sector is bounded by the list of potential impacts of the climate change. These are: Shortening of maturity period, Expanding crop diseases, Low productivity, and Crop failure.

3. CROP DIVERSITY AND CLIMATE CHANGE ADAPTATION

3.1. Crop Diversity

Crop diversity is the variance in genetic and phenotypic characteristics of plants used in agriculture. Crops may vary in seed size, branching pattern, in height, flower color, fruiting time, or flavor. They may also vary in less obvious characteristics such as their response to heat, cold or drought, or their ability to resist specific diseases and pests. It is possible to discover variation in almost every conceivable trait, including nutritional qualities, preparation and cooking techniques, and of course how a crop tastes. And if a trait cannot be found in the crop itself, it can often be found in a wild relative of the crop; a plant that has similar species that have not been farmed or used in agriculture, but exist in the wild (Biodiversity International, 2008).

Plant responses to many stresses, both biotic (such as pathogens or pests) and abiotic (such as drought or temperature extremes) are at least partly under genetic control (examples will follow). Thus, flexibility in response to these stresses is increased when there is relatively more genetic diversity present at the population or landscape levels. Greater flexibility means greater stability in production, as entire fields (or crops, at the landscape level) are less likely to be weakened or eliminated by pests, pathogens, or extremes of climate (Oregon state University, 2011)

Diversified agro-ecosystems have become more important for agriculture as climate fluctuations have increased. Research has shown that crop yields are quite sensitive to changes in temperature and precipitation, especially during flower and fruit development stages. Temperature maximums and minimums, as well as seasonal shifts, can have large effects on crop growth and production. Greater variability of precipitation, including flooding, drought, and more extreme rainfall events, has affected food security in many parts of the world (Parry et al. 2005).

A variety of research has shown that high plant diversity within agricultural plots can yield higher production levels than systems with low plant diversity. Grassland experiments have shown that greater plant species diversity is correlated with greater temporal stability in annual aboveground plant production, demonstrating that a more efficient and sustainable supply of food, such as fodder, can be enhanced by increasing biodiversity (Tilman et al. 2006).

3.2. Crop Diversity for Climate Change Adaptation

Many farmer adaptations to climate variability center on diversification to take advantage of the differential effects that a given climate event or condition might have on different crops and activities during the year. For example, in rain fed systems that are prone to drought, diversification of farm plot locations can take advantage of spatial variability in rainfall. The most common diversification strategy identified by the reviewed studies was to grow a variety of crops (Bryan et al.2009, 2013)

The production of food crops is the most climate-dependent economic activity. Changes in climate can be expected to have significant impacts upon crop yields through changes in both temperature and moisture. As climate patterns shift, changes in the distribution of plant diseases and pests may also have adverse effects on agriculture (Burton 2006).

Forecasts for declines in the yields of staple crops show that climate change will place unprecedented pressures on our ability to grow the food we require, and these impacts will be particularly severe in developing countries. The need for new crop varieties that can withstand these challenges is now widely recognized and is frequently cited in climate change discussions. These are essential not only to reduce hunger but also to strengthen global food security in the medium- and long term. Therefore the development of crop varieties that can cope with heat, drought, flood and other extremes may well be the single most important step we can take to adapt to climate change. https://www.croptrust.org/our-mission/crop-diversity-why-it-matters/ (Accessed date 7/10/2016)

In many areas, the crop varieties and species currently grown by farmers cannot tolerate these stresses, with resultant losses in productivity, and potentially negative consequences for food security. as climate change related stresses exceed the adaptive capacity of crops grown in particularly vulnerable areas, the countries affected will become increasingly dependent on germplasm of crops, forages and wild relatives that have evolved in other parts of the world, possibly in neighbouring countries, or on other continents The ability of farmers, plant breeders and natural resource managers to identify and access such germplasm is becoming increasingly important as climates continue to change (Halewood et al, 2013).

Diversification is one way to give farmers more options in times of need. With little access to a diversity of crops and varieties, farmers are more likely to cope with the effects of climate change. But farmers do not always have the information or planting material to choose what diversity best suits their conditions (Biodiversity International).

http://www.bioversityinternational.org/research-portfolio/adaptation-to-climate-change/seeds-for-needs/

Between 2010 and 2012 Biodiversity International worked with partners and stakeholders in Ethiopia to develop an innovative low-cost strategy for managing risks to agricultural systems posed by the adverse effects

of climate change. The objective, which the project indeed achieved, was to decrease vulnerability and enhance adaptive capacity in smallholder farming communities by increasing the intraspecific diversity of important food security crops using barley and durum wheat (Gotor et al, 2014).

Using agricultural biodiversity in the fight against climate change is about building climate smart systems - responding to variety *with* variety. Diversity can help farmers mitigate, adapt and ensure food and nutrition security, by providing them with more options to manage climatic risks and strengthen the resilience of their farms and surrounding landscapes (biodiversity international). http://www.bioversityinternational.org/research-portfolio/adaptation-to-climate-change/ (Accessed date 02/10/2.16)

The more different crops the farmer grows, the lower must be the risk, since at least some of his crops are likely to tolerate the weather conditions, and the pest outbreak is extremely unlikely to affect each of his crops (Edward, 1991).

Goldsmith has also given more explanation about the importance of crop diversity saying: Plants also complement each other with regards to nutrient cycling, thus deep-rooted plants can act as "nutrient pumps" bringing up minerals from deep down in the sub-soil. Minerals released by the decomposition of annuals are taken up by perennials. The nutrient-intensity of some plants is compensated for by the addition of organic matter to the soil by others. Thus cereals benefit by being grown in conjunction with legumes which have deeper roots permitting a better use of nutrients and of soil moisture and on whose root-nodules live species of bacteria specialized in fixing nitrogen. Maize and sorghum for instance can advantageously be grown together with legumes such as cow peas and rye grass.

Genetic information held in certain crop varieties is crucial to the development of heat, drought, salinity, pests and diseases-resistant, fast-growing, high-yielding new varieties, necessary to combat food insecurity in the face of climate change (FAO, 2010).

Crop diversity is agriculture's greatest resource for adaptation, the foundation for future efforts to feed the world. As we move into an uncertain, weather-dominated tomorrow, crop researchers need to keep answering new problems. The Seeds for Needs approach in Ethiopia has proven to be a cost effective solution to climate change adaptation since it provided fast solutions to counter climate variability compared to improved varieties in use (Gotor et al, 2014, p7).

3.3. Drought Resistant Crops in Ethiopia

Drought stress is a serious agronomic problem contributing to severe yield losses worldwide. This agricultural constraint may nevertheless be addressed by developing crops that are well adapted to drought prone environments. Drought tolerance depends on the plant developmental stage at the onset of the stress syndrome (P.K Sabadin et al, 2012).

With the expected climate-induced changes in sowing and harvest dates, farmers, if using the presently cultivated varieties, might face higher risks for food production. Furthermore, climatic patterns, particularly rainfall, are likely to become more erratic and less predictable, requiring farmers to make more frequently tactical adjustments (re-sowing and ad-hoc change of variety or crop, etc.) and to resort to "safer" (risk averting) crop options, involving trade-offs in terms of productivity (Folkard Asch, 2007).

3.3.1. Enset (false banana)

Enset is a plant native to Ethiopia that is often referred to as the false banana because, not surprisingly, of its resemblance to the banana plant. It is grown in the less arid highlands of the southwestern region of Ethiopia. Enset contributes to improved food security for approximately 15 million Ethiopians and, according to Ethiopian researchers, there is potential for expanding consumption of the crop (foodtank.com). http://foodtank.com/news/2013/09/enset-the-drought-resistant-miracle-plant (Accessed date 09/10/2.16)

According to the food tank, due to its resilience, nutritional value, and versatility, Ethiopians have been relying on enset as a staple crop for thousands of years. In addition to these characteristics, however, enset has proven to be a valuable asset for food security in times of drought.

The molecular structure of the plant gives it the ability to hold in moisture for extended periods of time. The plant has been known to not only survive drought, but provide water to plants growing next to it. Because of its unique ability to lock in moisture, it lends itself to become globally recognized as an environmentally sustainable agricultural system. Not only do the leaves help shade the soil beneath it, conserving water, but the plant also has the ability to prevent the soil from erosion during heavy rainfall.

Fig. 1: Image of Enset on Farm
Source: http://foodtank.com/news/2013/09/enset-the-drought-resistant-miracle-plant

Enset is farmed in a mixed system along with grain crops, coffee and others. Its main product is the starchy pith of its massive "pseudo-stem", which is pulped and then fermented in a big bundle, buried underground for 3 to 6 months, to produce "kocho" a solid staple a bit like a heavy bread which is eaten with milk, cheese, cabbage, meat and/or coffee (Alex McCausland, 2010).

3.3.2. Sorghum bicolor

Sorghum is a particularly drought-tolerant grain and an essential part of the diet for 500 million people, chiefly in sub-Saharan Africa and India. In the U.S., where it is primarily grown for livestock feed, sorghum's climate resilience was highlighted during the devastating summer drought of 2012 (Steven Powell**,** 2013).

The great advantage of sorghum is that it can become dormant under adverse conditions and can resume growth after relatively severe drought. Shoot removal lowers its capacity to withstand drought. Early drought stops growth before floral initiation and the plant remains vegetative; it will resume leaf production and flower when conditions again become favorable for growth. http://www.fao.org/ag/agp/agpc/doc/gbase/data/pf000319.htm (Accessed date 12/10/2.16)

Like corn, sorghum can be grown under a wide range of soil and climatic conditions. Unlike corn, however, sorghum's yield under different conditions is not so varied. Consequently, it is grown primarily in arid areas where corn wouldn't make it without substantial irrigation. Sorghum is an important part of the diets of many people in the world. It is made into unleavened breads, boiled porridge or gruel, malted beverages, and specialty foods such as popped grain and syrup from sweet sorghum.

http://oklahoma4h.okstate.edu/aitc/lessons/extras/facts/milo.html (Accessed date 12/10/2.16)

Sorghum – a grain, forage or sugar crop – is among the most efficient crops in conversion of solar energy and use of water. Sorghum is known as a high-energy, drought-tolerant crop. Because of its versatility and adaptation, "sorghum is one of the really indispensable crops" required for the survival of humankind (From Jack Harlan, 1971) as cited by National Sorghum Producers, 2006, www.sorghumgrowers.com/Sorghum+101 (Accessed date 12/10/2.16)

According to the same source, the inherent tolerance of sorghum to marginal lands and environmental conditions, its versatility as a food and feed grain, and its ability to produce high yields ensure its important role

in the lives of millions of people throughout the world.

3.3.3. Sweet potato

Sweet potatoes (Ipomoea batatas) are a delicious crop that is high in vitamin content. It is a warm season crop that grows best in long, hot growing seasons. There are many varieties to choose from, with shorter maturity varieties suited to cooler climates. Sweet potatoes are members of the morning glory family, are relatively pest free, and can be stored for a long time after harvest (Jeran Farley and Dan Drost, 2010).

It grows well in many farming conditions and has few natural enemies; pesticides are rarely needed. Sweet potatoes are grown on a variety of soils, but well-drained, light- and medium-textured soils with a pH range of 4.5-7.0 are more favorable for the plant (*Woolfe and Jennifer, 1992).*

The plant does not tolerate frost. It grows best at an average temperature of 24 °C (75 °F), abundant sunshine and warm nights. Annual rainfalls of 750–1,000 mm (30–39 in) are considered most suitable, with a minimum of 500 mm (20 in) in the growing season. The crop is sensitive to drought at the tuber initiation stage 50–60 days after planting, and it is not tolerant to water-logging, as it may cause tuber rots and reduce growth of storage roots if aeration is poor **(***Ahn, Peter (1993).*

In Ethiopia, the commonly found varieties are black-skinned, cream-fleshed and called "bitatis" or "mitatis". They are cultivated in the eastern and southern lower highlands and harvested during the rainy season (June/July). In recent years, better yielding orange-fleshed varieties were released for cultivation by Haramaya University as a less sugary sweet potato with higher vitamin A content. Sweet potatoes are widely eaten boiled as a favored snack providing calories and carbohydrates (Tekalign and Niguse, 2008).

3.3.4. Drought Tolerant Maize (DTM)

Maize is the most important cereal crop in sub-Saharan Africa (SSA) and an important staple food for more than 1.2 billion people in SSA and Latin America. All parts of the crop can be used for food and non-food products (IITA, 2009).

Maize is the most important food crop in Sub-Saharan Africa, where it is almost completely rainfed and, therefore, dependent on the region's increasingly erratic precipitation. Around 40 % of Africa's maize-growing area faces occasional drought stress in which yield losses are 10–25 %. Around 25 % of the maize crop suffers frequent drought, with losses of up to half the harvest (CIMMYT, 2013). To reduce vulnerability and improve food security, the **Drought Tolerant Maize for Africa** (DTMA) project has made releases of 160 drought tolerant (DT) maize varieties, between 2007 and 2013 (Fisher et al, 2015).

Similar source indicated that, The DT maize varieties have been bred using modern conventional methods, without genetic modification. In addition to drought tolerance, the varieties have other attractive traits, such as resistance to major diseases and high protein content. The DT maize varieties have similar labor requirements and seed costs as non-DT commercial varieties.

Results of the work of Fisher et al (2015) show that major barriers to adoption of DT maize include unavailability of improved seed, inadequate information, lack of resources, high seed price, and farmers ' perceptions of variety attributes Differences in the main adoption constraints among countries are revealing. The key constraints are unavailability of improved seed and lack of resources in Ethiopia. If these constraints are avoided in the country, the opportunity has potential to enable Ethiopian farmers to adapt to the climate change.

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